The Accelerator Challenge - from 10^{32} to 10^{34} to 10^{36}

Jonathan Dorfan
Director Emeritus, SLAC

10^{32} to 10^{34} cm^{-2} sec^{-1}

The Era of the mid 1980s to mid 2000s

1989

WHAT HAS LED TO THE INTENSE INTEREST IN CP VIOLATION IN B?

- ARGUS & CLEO HAVE MEASURED LARGE MIXING IN B^0 / $\overline{B}^0$ SYSTEM
- B LIFETIME IS LONG ($\gtrsim 1$ psec)
- SILICON VERTEX METHODS REPRESENT A NEW LEVEL OF DETACHED VERTEX PRECISION MARK II, DELPHI

PROSPECT OF MEASURING CP IN B MESON SYSTEM LOOKS MUCH BRIGHTER

- THIS WOULD BE THE FIRST OBSERVATION OF CP VIOLATION OUTSIDE OF THE K^0 SYSTEM
- SUCH MEASUREMENTS WOULD CONSTRAIN THE STANDARD MODEL IN A VERY STRINGENT MANNER

S.M. OK

S.M. FAILS

This led to at least 21 *e+e-* *B* Factory concepts and proposals (19 $\Upsilon(4S)$ + 2 $Z0$) and several hadronic machine approaches (HERA-B, ..

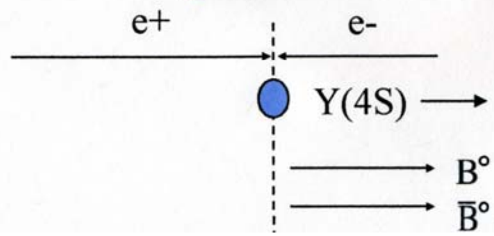
Table Courtesy David Hitlin

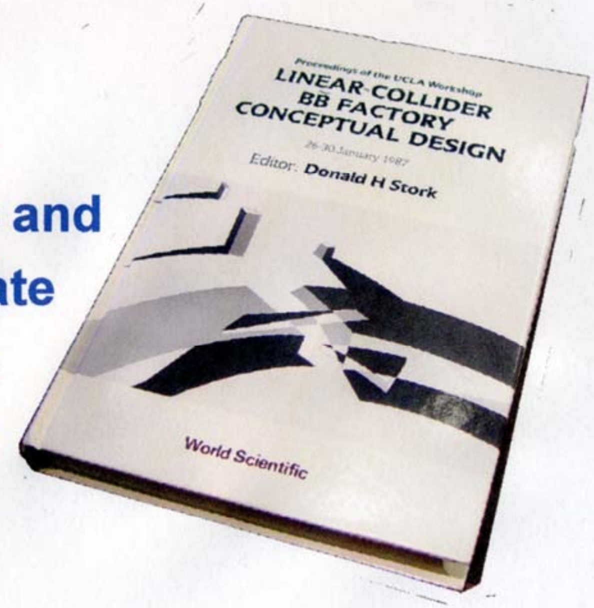
$\Upsilon(4S)$ Storage Rings		$\Upsilon(4S)$ Linac-Ring Collider	$\Upsilon(4S)$ Recirculating Linear Collider	Z Factory
Symmetric	Asymmetric			
PSI (2)	APIARY	Grosse-Wiesmann	Amaldi/Coignet	SLC
Novosibirsk	CITAR	JLAB	ARES	LEP
KEK accumulator	PEP-II		UCLA	
CESR Plus	PETRA		TBA	
	ISR Tunnel			
	KEK accumulator			
	KEK-B			
	CESR-B			

Pier Oddone's concept of using an asymmetric *e+e-* collider to boost the distance between the two decay vertices was, in the end, the most successful approach. Two colliders, PEP-II and KEKB, were ultimately built

Things Come Together January 1987

- Discussions with Ikaros Bigi and Tony Sanda
- "Crazy Asymmetric Idea" just what was needed for CP studies
- Could be done by modifying PEP
  - Two rings: give high luminosity
  - $\Upsilon(4S)$: gives high cross section and $B^{\circ}\overline{B}^{\circ}$ in coherent state
  - Asymmetry: separated vertices give time evolution

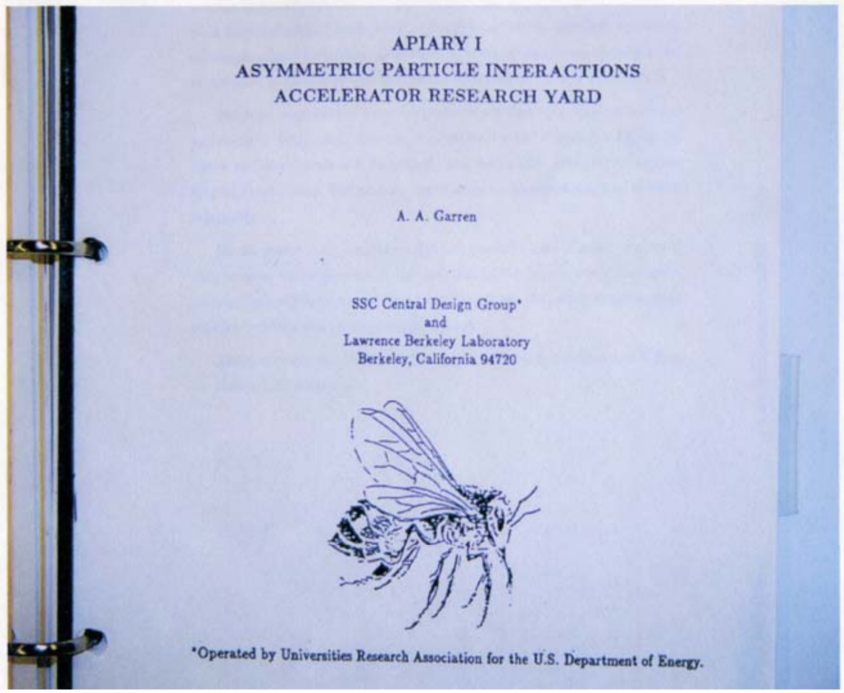




Slide Courtesy of Pier Oddone

Next thrust: Apiaries…..

- **APIARY 1: June 1988**



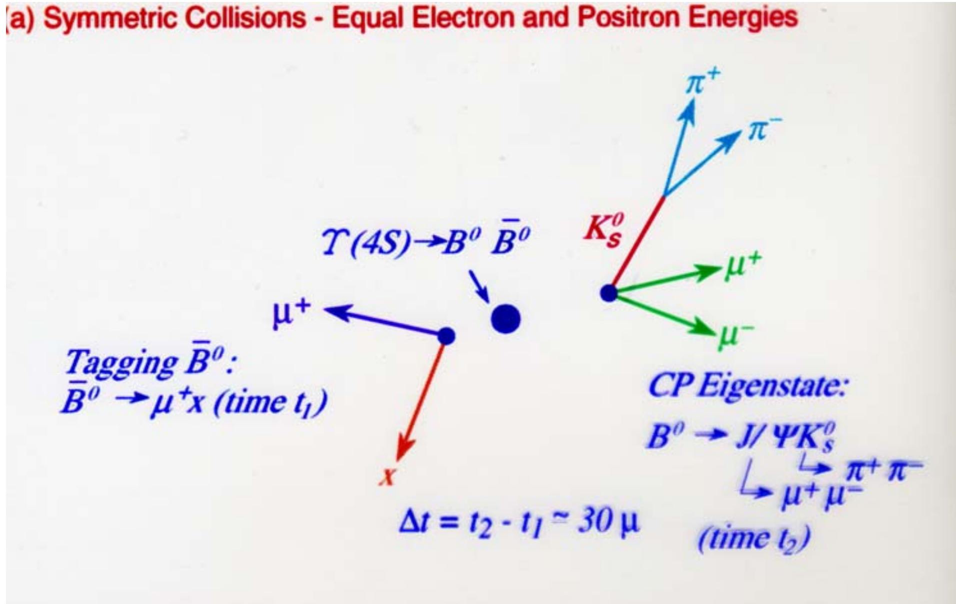
APIARY I
ASYMMETRIC PARTICLE INTERACTIONS
ACCELERATOR RESEARCH YARD

A. A. Garren

SSC Central Design Group*
and
Lawrence Berkeley Laboratory
Berkeley, California 94720

*Operated by Universities Research Association for the U.S. Department of Energy.

Slide Courtesy of Pier Oddone


(a) Symmetric Collisions - Equal Electron and Positron Energies
π+
π−
Υ(4S)→B0 B̄0
K0S
μ+
μ+
μ−
Tagging B̄0:
B̄0 → μ+x (time t1)
x
CP Eigenstate:
B0 → J/ΨK0S → π+π− → μ+μ−
(time t2)
Δt = t2 - t1 ~ 30 μ

So What Were the Key Challenges ?

1) Technical

2) Quality Control *without* Compromising Integrated Luminosity or Budget or Schedule

1) Technical Challenges

Physics Requirements

1. Integrated luminosity of $\geq 30\ \text{fb}^{-1}$ / year
   This corresponds to

$$\begin{cases} \mathscr{L}_{\text{peak}} = 3\text{x}10^{33}\ cm^{-2}\ \text{sec}^{-1} \\ 2x10^{7}\ \text{seconds} \\ \varepsilon \simeq 50\,\% \end{cases}$$

2. Two storage rings colliding asymetrically at $\Upsilon(4s)$ with $E_{hi} \geq 8$ GeV

3. Beampipe radius $\leq 3\ cm$

4. Detector well instrumented for
   $$-0.95 \leq \text{Cos}\theta_{cm} \leq 0.9$$
   This corresponds to restricting the machine components to $\theta_{lab} \leq 300$ mrad in forward direction

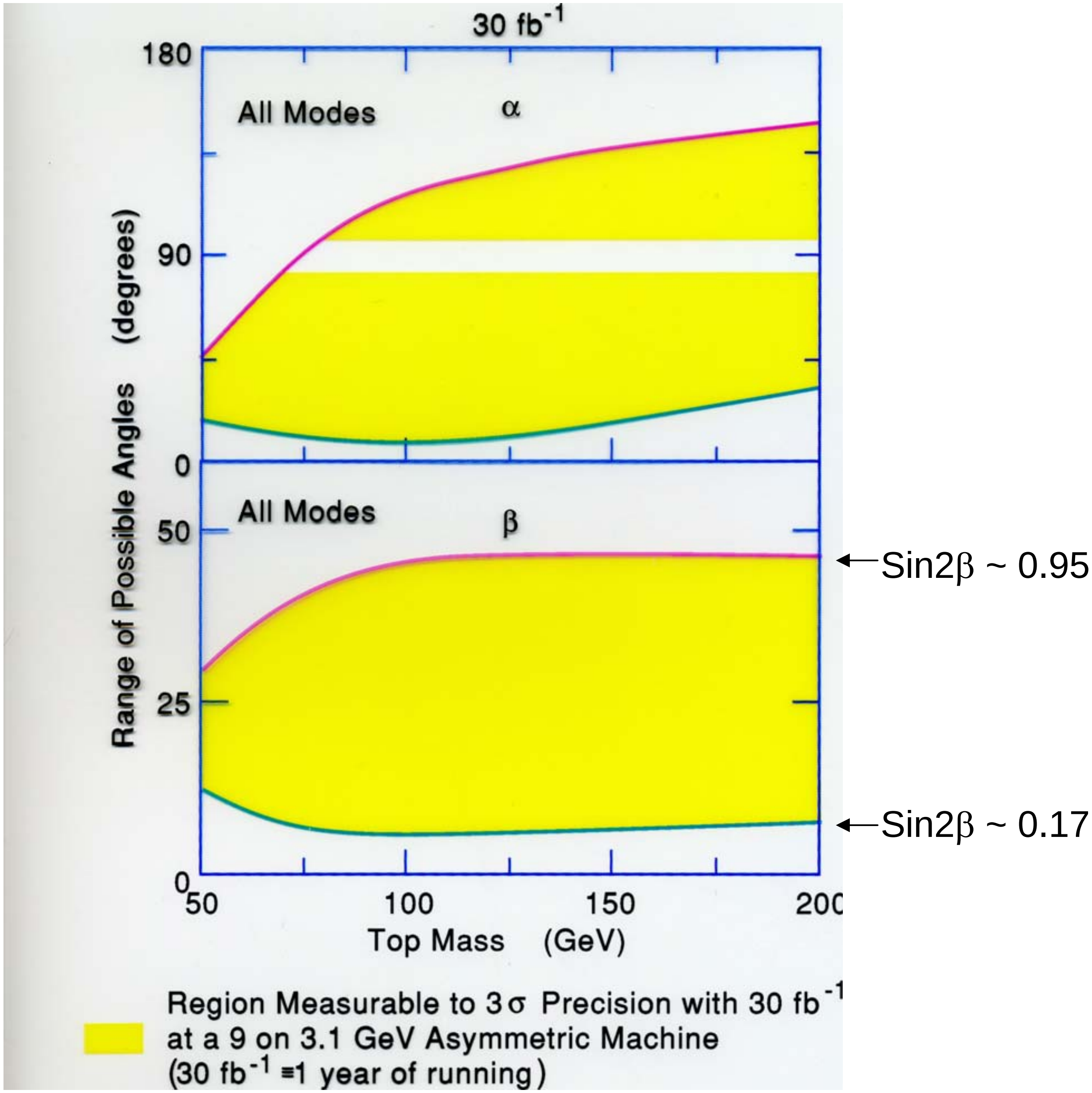
Given the critical importance of the CP physics, it is most desirable to have two *B*-Facories in the world

$30\ \text{fb}^{-1} = 3.3\ 10^{7}$ BB events

Integrated $\mathscr{L}$ Benchmarks:

- CESR: 10^5 BB/yr in 1987
- CESR:1.1-1.5 fb^{-1}/yr, average 1991-1995

1990


30 fb⁻¹
180
90
0
50
25
0
50
100
150
200
All Modes
α
All Modes
β
Range of Possible Angles (degrees)
Top Mass (GeV)
Region Measurable to 3σ Precision with 30 fb⁻¹
at a 9 on 3.1 GeV Asymmetric Machine
(30 fb⁻¹ ≡1 year of running)
Sin2β ~ 0.95
Sin2β ~ 0.17

1991

Choices for $\mathscr{L}$ Optimization are not Wide Ranging:

$$\mathscr{L} = 2.17\times10^{34}\,(1+r)\,\Delta\nu\left(\frac{E(\mathrm{GeV})\;\;I(\mathrm{amps})}{\beta_y^*\,(\mathrm{cm})}\right)^{+,-}$$

$E^{+,-} \rightarrow$ Given by physics

$\beta_y^* \rightarrow$ Limited to $\gtrsim 1$ cm by bunch length and practical considerations

$\Delta\nu \rightarrow$ Beam-beam sets this; Not really a parameter

$0<r<1 \rightarrow$ r is aspect ratio of beams (flat/round). Practical considerations make round beams unmanageable

$\Rightarrow$ Route to HIGH luminosioty is HIGH circulating currents

↳ Single beam instabilities force you to large # bunches

↳ Forces you to two separate rings

7-91 6555A48

What are the technical challenges of *B*-Factory?

Requirements of high current, large number of bunches and hetero-energetic beams leads to:

- ⁎ Need a powerful injector, especially for e^+. Currents are high and beam lifetimes are short (≤ 2 hours)
- ⁎ Large synchrotron radiation load. Both thermal management and especially low pressure management are challenging
- ⁎ Must provide protection against multibunch instabilities. Bunch spacing $\sim 1m$
- ⁎ Must provide interaction region optics which both focuses and separates hetero-energetic beams and keeps the backgrounds to acceptable levels
- ⁎ Must have factory performance

The *B*-Factory is thus more of an engineering challenge than an accelerator-physics groundbreaker

1990

CHARACTERISTICS OF PEP II DESIGN: GUIDING PRINCIPLES

- ☐ DESIGN MUST BE CONSERVATIVE AT $\mathcal{L} = 3\ 10^{33}$ cgs
- ☐ MUST BE FACTORY PRODUCING 30 fb^{-1}/year
- ☐ MUST ACHIEVE DESIGN SPECIFICATIONS SOON AFTER TURN-ON
  - MAKE DESIGN FLEXIBLE
  - PROVIDE "HEADROOM" / TECHNICAL MARGIN
  - STRESS RELIABILITY; HAVE ENGINEERING STAFF BUILD IT IN FROM THE START
  - CHOOSE PROVEN TECHNIQUES AS MUCH AS POSSIBLE - DO ADEQUATE R&D IN NON-STANDARD AREAS
  - IDENTIFY AS COMPLETE A SOLUTION AS POSSIBLE FROM THE START. IDENTIFY THE MONEY REQUIRED TO IMPLEMENT THIS SOLUTION

1990

EXAMPLES FROM PEP II DESIGN:

FLEXIBILITY; "HEADROOM"; ABILITY TO UPGRADE LUMINOSITY

- VACUUM CHAMBER IS DESIGNED FOR 3 AMPS; NOMINAL CURRENTS ARE 2.1 AND 1.5 AMPS
- INJECTOR HAS LOTS OF SPARE CAPACITY -- IT WILL STILL PROVIDE SHORT FILLING TIMES ON THOSE DAYS WHEN TRANSMISSION IS POOR
- STRONG WIGGLERS ARE INCLUDED WHICH ARE CAPABLE OF ENSURING EQUAL DAMPING DECREMENTS FOR BOTH BEAMS SHOULD THIS PROVE IMPORTANT (ENERGY TRANSPARENCY)
- TUNE SHIFT IS TAKEN TO BE $\Delta\nu$ =0.03. PEP RAN WITH $\Delta\nu$=0.06
- VERY ADAPTIVE FEEDBACK SYSTEM -- CAPABLE OF DAMPING ANY TRANSVERSE OR LONGITUDINAL PERTURBATION. FACTOR OF ~2 MORE POWER BUDGETED THAN SIMULATIONS INDICATE IS NEEDED
- MACHINE IS EASILY CONVERTED TO FINITE CROSSING ANGLE BY CHANGING ONLY IR COMPONENTS. CRAB-CROSSING CAN BE ADOPTED IF PROVEN FEASIBLE/ADVANTAGEOUS

1990

Changing the Center-of-mass
Energy of the PEP-II *B* factory.

Michael K. Sullivan
May 24, 1993

INTRODUCTION.

All *B* factory designs are optimized to run at the center-of-mass energy (W_{cm}) of the $\Upsilon(4S)$ resonance of the Υ family (10.580 GeV). This note investigates the effect changing W_{cm} has on the design orbits of the beams. The design under study is APIARY 7.5. Methods are shown that attempt to minimize changes in the beam orbits while spanning the 1S to 5S resonances of the Υ

Resonance	W_{cm} (GeV)	ΔW_{cm} %	E_1 (GeV)	E_2 (GeV)	ΔE_1 %	ΔE_2 %
5S	10.865	+2.7	3.1883	9.2564	+2.7	+2.7
4S	10.580	≡ 0.0	3.1047	9.0136	≡ 0.0	≡ 0.0
3S	10.355	−2.1	3.0386	8.8219	−2.1	−2.1
2S	10.023	−5.3	2.9412	8.5390	−5.3	−5.3
1S	9.460	−10.6	2.7760	8.0594	−10.6	−10.6

Constant opening angle constraint.

Resonance	E_1 (GeV)	E_2 (GeV)	ΔE_1 %	ΔE_2 %	IP angle (mrad)
5S	3.1468	9.3784	+1.4	+4.0	−0.27
4S	3.1047	9.0136	≡ 0.0	≡ 0.0	≡ 0.0
3S	3.0704	8.7306	−1.1	−3.1	+0.25
2S	3.0182	8.3212	−2.8	−7.7	+0.65
1S	2.9250	7.6490	−5.8	−15.1	+1.60

WHY THE EMPHASIS ON THE LINAC?

HIGH PEAK LUMINOSITY IS NOT THE WHOLE STORY; $\langle \mathcal{L} \rangle$ IS.

$\mathcal{L}$ LIFETIME AT B FACTORIES WILL BE 1-2 HOURS

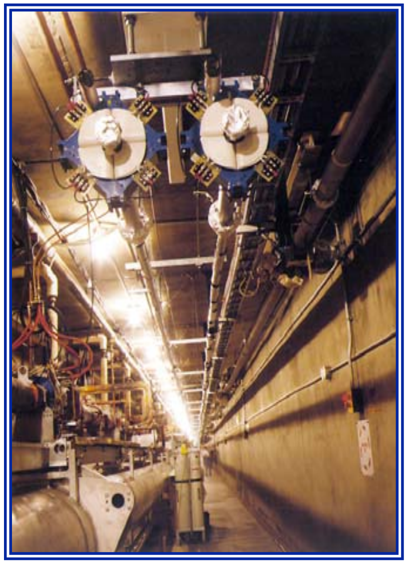
$\Rightarrow$ IMPERATIVE THAT ONE BE ABLE TO INJECT AND TOP-OFF VERY RAPIDLY, VERY OFTEN.

B FACTORIES HAVE $e^{\pm}$ CURRENTS OF 1-2 AMPS

TO MAINTAIN GOOD $\langle \mathcal{L} \rangle$ IMPLIES INJECTING ABOUT $\underline{5 \times 10^{13}\ e^+, e^-}$ IN PERIOD VERY SHORT COMPARED TO AN HOUR. THIS IS DIFFICULT FOR e^-, EXTREMELY DIFFICULT FOR e^+.

WE ARE VERY FORTUNATE AT SLAC TO HAVE A LINAC WHICH DELIVERS $2 \times 10^{10}\ e^+, e^-$ @ 120 HZ. OUR ESTIMATES ARE THAT WE CAN FILL THE B FACTORY IN $\leq$ 2 MINUTES.

Cornell Workshop
Sept 1990



Built dedicated on-energy
Injection lines in linac tunnel

Cornell Workshop
Sept 1990

WHATS WRONG WITH CURRENT ALUMINUM GEOMETRY CHAMBERS WRT B FACTORY ?

(CURRENT IN HER ≈ 1 AMP)

① CANNOT HANDLE HEAT LOAD

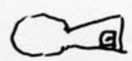
$E(\text{GeV}), I(\text{mAmp}), \rho(\text{m})$

$$\text{LINEAR POWER DENSITY (W/cm)} = \frac{0.88\, E^4 I}{\rho^2}$$

② CANNOT PUMP CHAMBER - DESORPTION TOO RAPID

$$\text{LINEAR GAS LOAD (TORR. LITRES/S/M)} = \frac{2.42\times10^{-2}\,\eta\, E I}{2\pi\rho}$$

η = DESORPTION COEFF; DEPENDS ON MATERIAL, AMOUNT OF SCRUBBING.

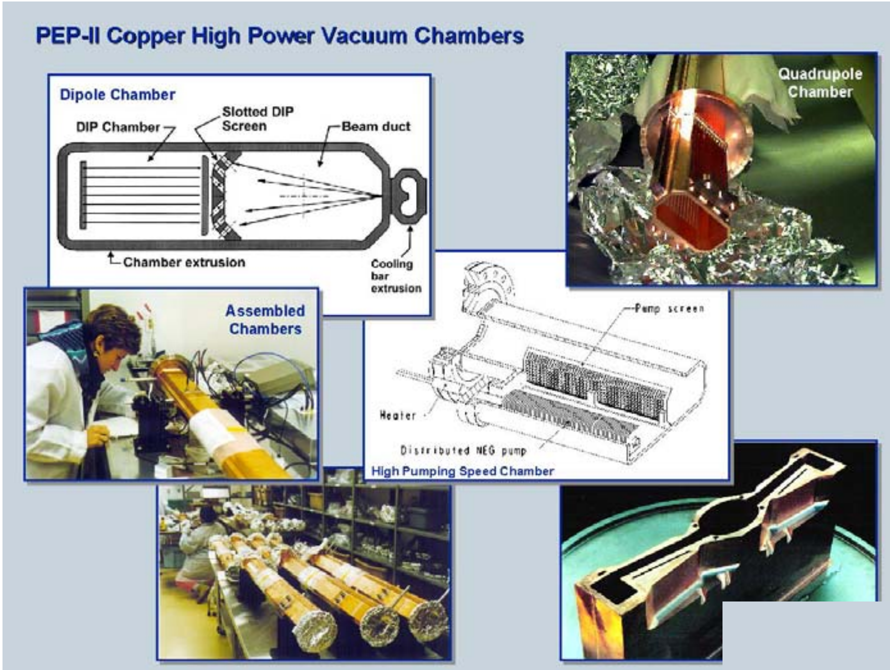
SOLUTIONS : 1) ALUMINUM ANTE / CHAMBER 

↳ DOESN'T FIT CONVENTIONAL MAGNETS, CUMBERSOME

2) STANDARD SIZE CHAMBER MADE FROM COPPER.

η SMALLER THAN ALUM., CONDUCTS A LITTLE BETTER

WE HAVE A DESIGN USING COPPER WHICH SOLVES THESE TWO PROBLEMS. EXAMPLE OF WHERE LARGE PEP RING RADIUS IS OF BENEFIT.


PEP-II Copper High Power Vacuum Chambers
Dipole Chamber
DIP Chamber
Slotted DIP Screen
Beam duct
Chamber extrusion
Cooling bar extrusion
Quadrupole Chamber
Assembled Chambers
Pump screen
Heater
Distributed NEG pump
High Pumping Speed Chamber


Low Energy Ring
Vacuum Chamber Processing
Magnet Chamber Oven
Pumping Chamber
TiN Coating of Pumping Chamber
Photon Stop

BACKGROUNDS COUPLED WITH BEAM SEPARATION ARE CLEARLY ONE OF THE LEADING CHALLENGES!

HOW DO WE PLAN TO SEPARATE THE BEAMS?

OUR PRIMARY SCHEME IS:

HEAD-ON COLLISIONS, MAGNETIC SEPARATION.

OUR PROPOSAL WILL ALSO HAVE A CRAB CROSSING OPTION, WITH SMALL (~ 25mrad) CRAB ANGLE.

IT HAS BEEN OUR DESIRE TO SEE IF WE COULD DESIGN A HEAD-ON SCHEME WITH ACCEPTABLE BACKGROUNDS.

→ WE BELIEVE WE HAVE DONE THIS. AT SNOWMASS WE WORKED VERY CLOSELY WITH CORNELL GROUP CHECKING IN GREAT DETAIL THE BACKGROUND SIMULATIONS. WE AGREED THAT THE MODELLING IS ACCURATE AND WE ARE NOT FOOLING OURSELVES.

→ WE ARE ONTO THE NEXT STEP NOW - DEMONSTRATE THAT THE IR REGION (MASKS, CHAMBER, MAGNETS, ..) CAN INDEED BE BUILT. ALSO CHECK SIMULATIONS ON TPC BACKGROUNDS.

Cornell Workshop
Sept 1990

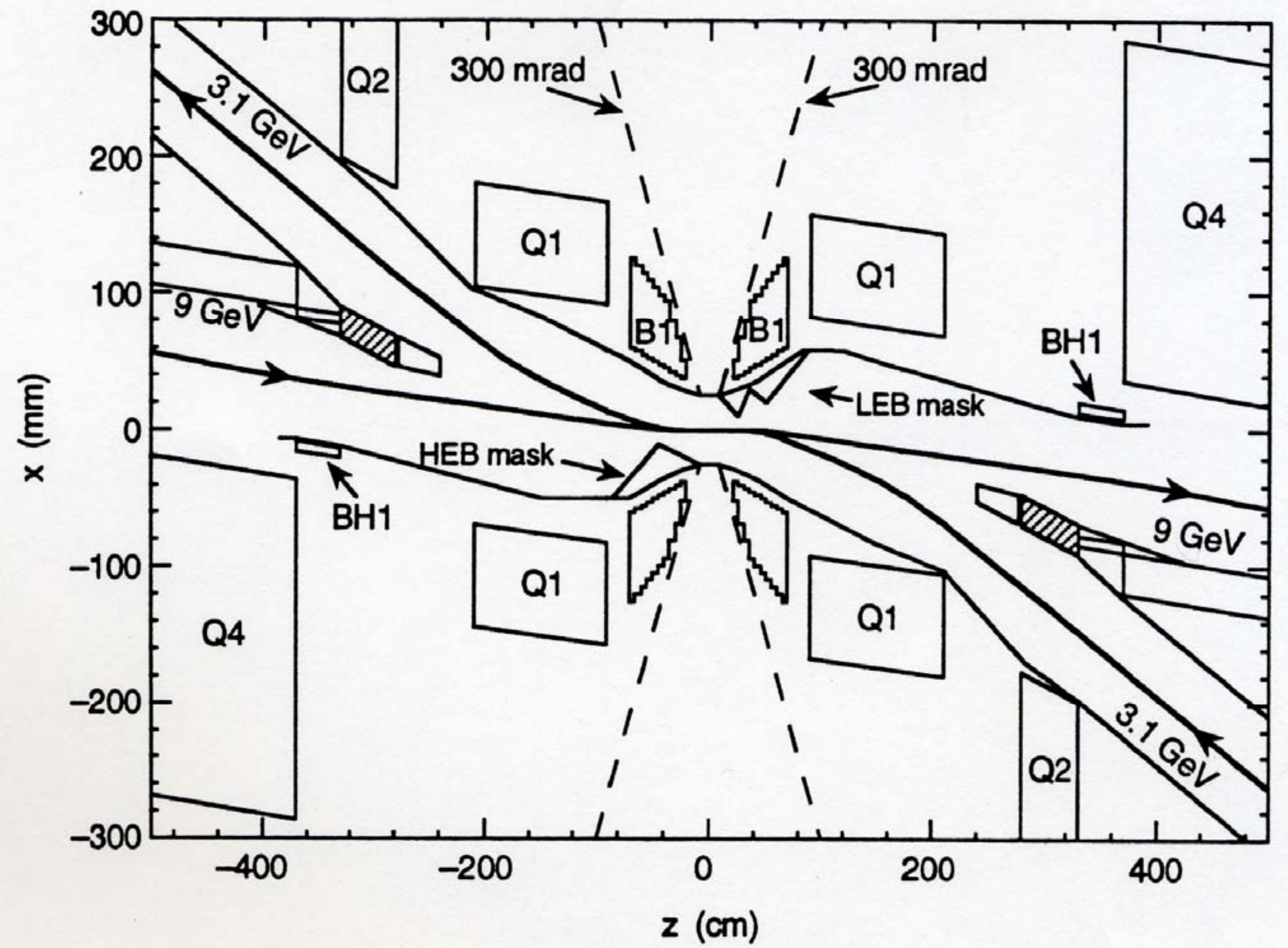
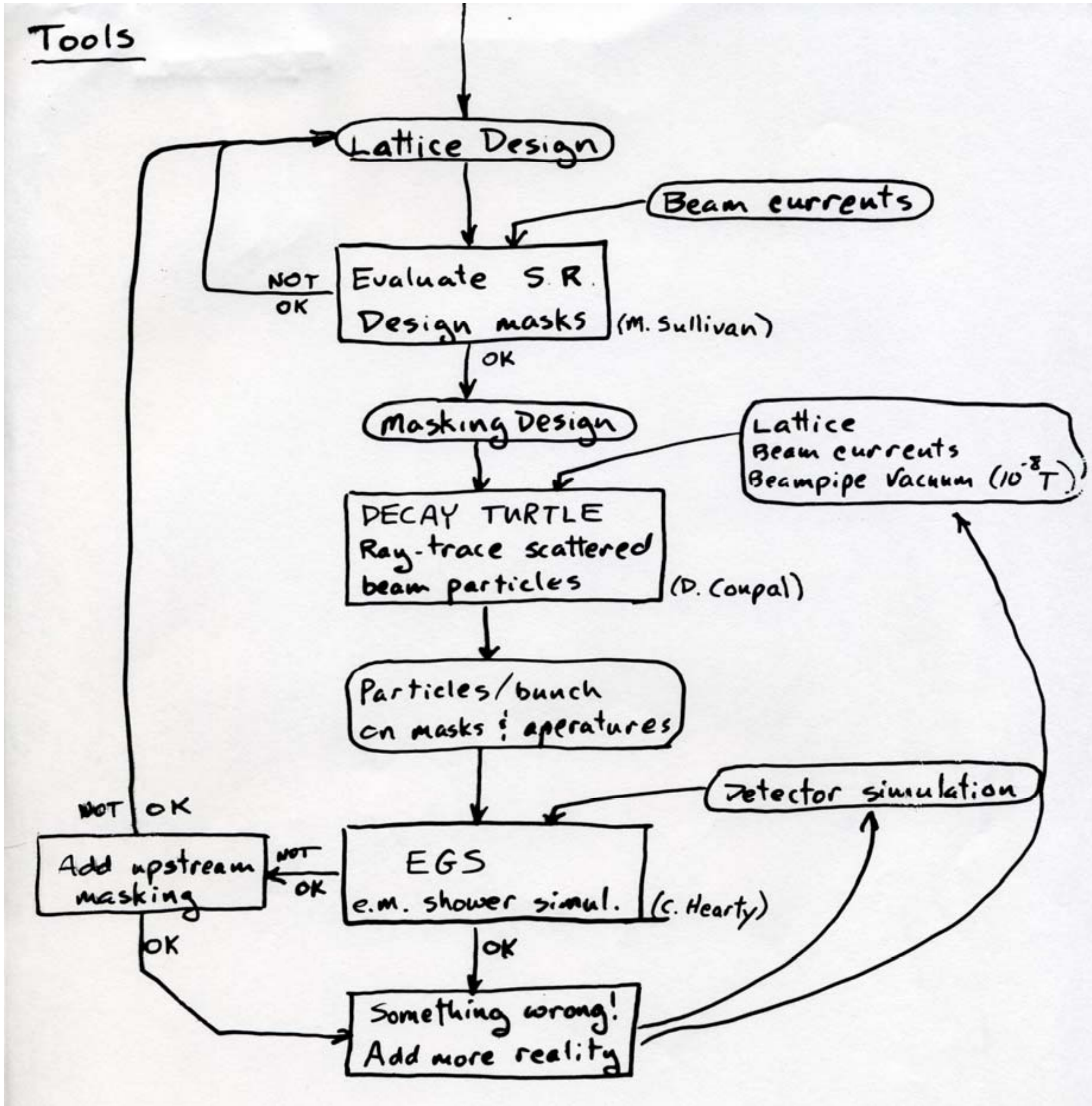


Figure 1. Layout of the interaction region. Note the highly exaggerated vertical scale.


Tools
Lattice Design
Beam currents
Evaluate S.R.
Design masks
(M. Sullivan)
NOT OK
OK
Masking Design
Lattice
Beam currents
Beampipe Vacuum (10^{-8} T)
DECAY TURTLE
Ray-trace scattered
beam particles
(D. Coupal)
Particles/bunch
on masks & aperatures
Detector simulation
NOT OK
Add upstream
masking
NOT OK
EGS
e.m. shower simul.
(C. Hearty)
OK
OK
Something wrong!
Add more reality

1990

Controlling single & multibunch instabilities

- ⁎ It is relatively easy to maintain a small broadband impedance by building "smooth" vacuum chambers
- ⁎ Multibunch instabilities arise from the interaction of bunches with resonant structures - RF Cavities
- ⁎ High-order-mode fields excited by bunch N will act on bunch N+1, N+2... quickly driving the beam unstable
- ⁎ Solution is to damp the HOM's while preserving the fundamental

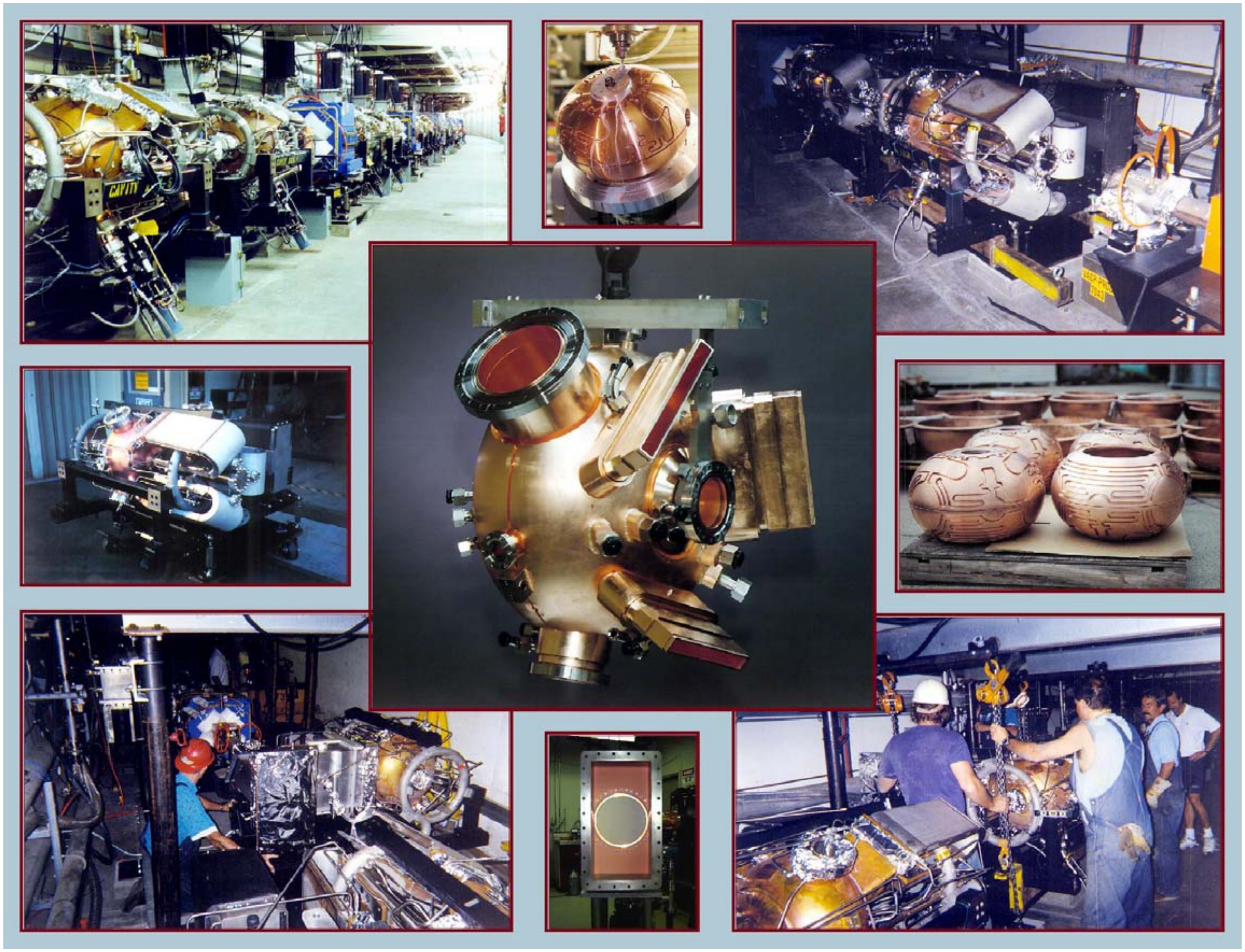
PEP-II: Warm copper cavities with HOM dampers

KEKB: Two-prong approach

(a) superconducting, wide-bore cavities with HOM dampers on the beampipe

(b) warm copper cavities with HOM dampers

1990



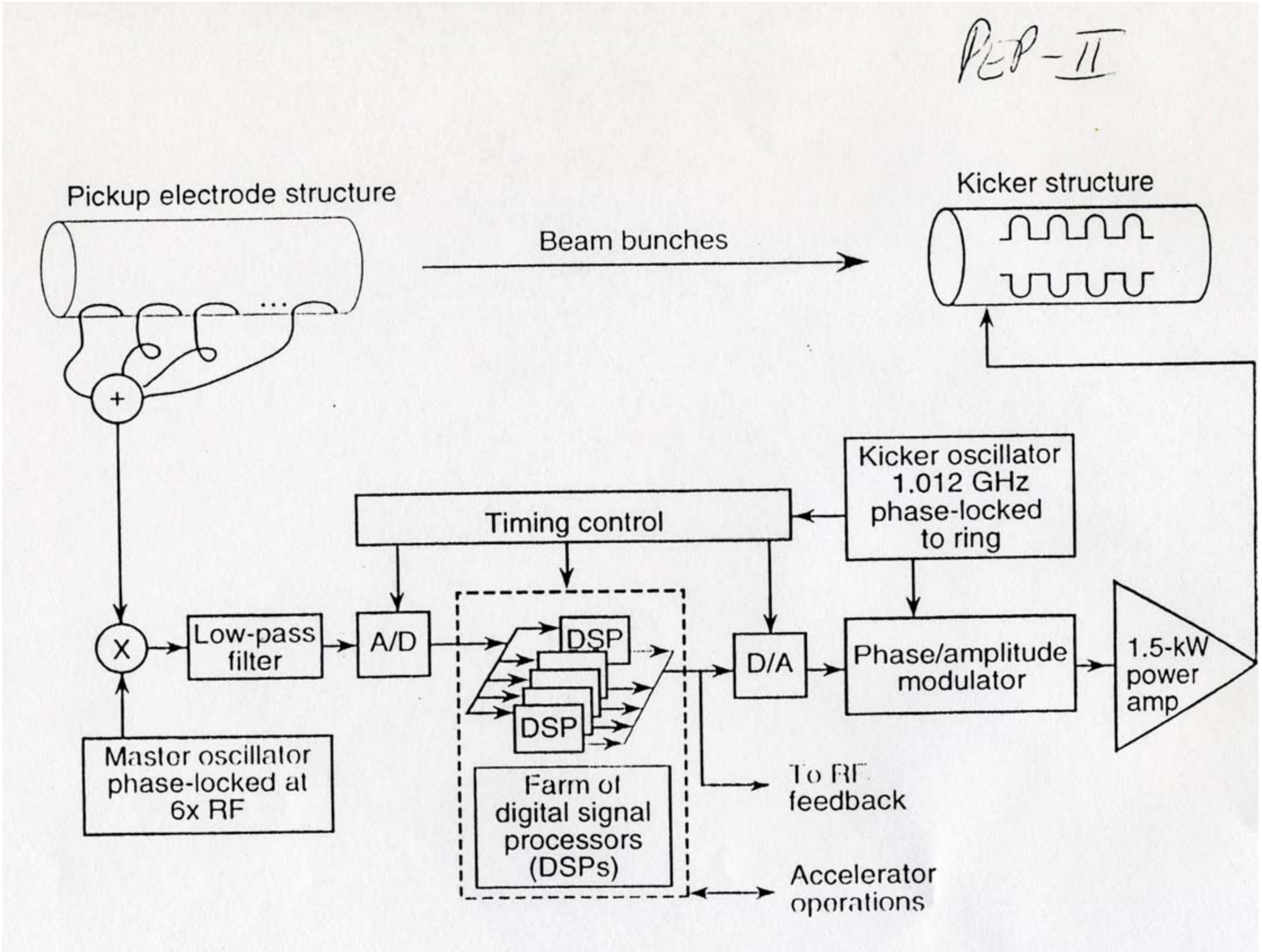


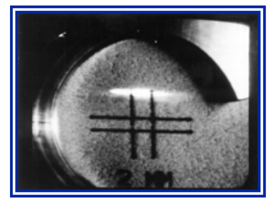
Fig. 5-114. Block diagram of the PEP-II longitudinal feedback system.

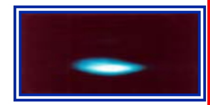
1991

2) Quality Control without Compromising Int.Luminosity or Budget or Schedule

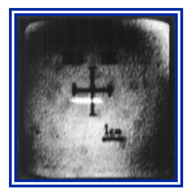
This was a constant vigil – it culminated with the strategy of *staged completion and testing* of the major subcomponents with real beam:

e^- (e^+) at end of New Injection Lines: Oct ’95 (97)

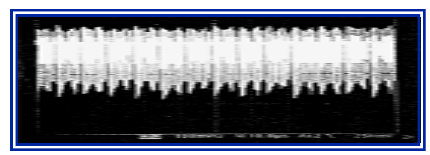




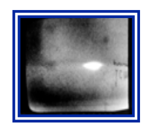
e- beam through 1/3 of HER : May ‘97



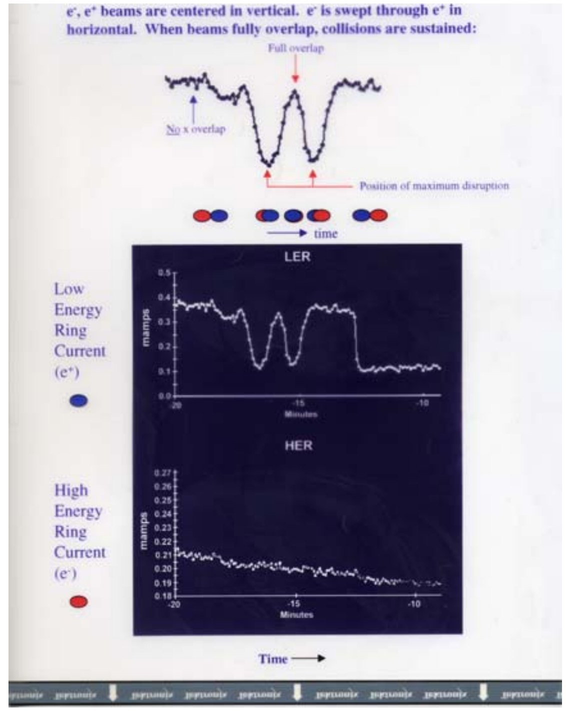
Stored e- beam in High Energy Ring: June ‘97



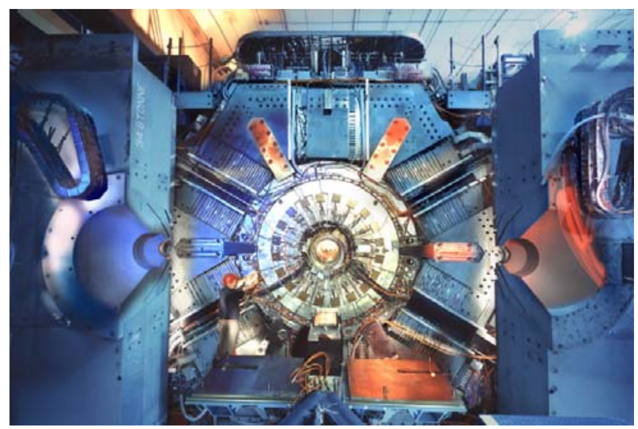
e+ beam to Low Energy Ring Arc 7 Temp. Dump: Jan 98



First Collisions: July ‘98



Following extensive cosmic ray checkout, BABAR moves onto beamline: Feb. ‘99



HER Commissioning Results

Parameter	Units	Design	"Best" by Feb 22, 1999
Energy	GeV	9.0	9.0, ramp to 9.1 and back
Single bunch current	mA	0.6	12
Number of bunches		1658	1658
Total beam current	A	0.995	0.75
y/x coupling	%	3.0	down to 0.8
RF voltage/cavity	MV	0.70	0.79
Synchrotron tune		0.045	0.0447
Bunch separation	m	1.26	0.63<--->2200
Chromaticity		-43, -54 (natural)	-43.6, -55.4 (natural)
Beam Lifetime	hours	4	10 hrs @ 50mA 8 hrs @ 270mA 2.5 hrs @ 725mA
Maximum Injection Rate	mA/s	2.1 @ 60Hz	2.5 @ 10Hz

LER Commissioning Results

Parameter	Units	Design	"Best by Feb 22, 1999
Energy	GeV	3.1	3.1
Single bunch charge	mA	1.3	7.0
Number of bunches		1658	1658
Total charge	A	2.14	1.171
RF voltage / cavity	MV	0.85	0.80
Synchrotron freq.		0.045	0.024
Bunch separation	m	1.26	1.26 ↔ 2200
Beam Lifetime		4 hours	50 min @ 800 mA
Maximum Injection Rate	mA / sec	5.9 @ 60Hz	3.0 @ 10 Hz

Overview

Goal of background measurements program is
to find and fix problems before BaBar rolls in

Multiple small detectors
some optimized for expected backgrounds,
some BaBar mimics and prototypes
built and operated by BaBar physicists

Start during HER commissioning with simplified IR,
compromise beampipe, subset of detectors

Requires detailed Monte Carlo simulation of both
machine configuration(s) and detectors

June run allowed initial shakedown of first detectors

Fall run has given first real quantitative results

January run will have more intensive studies

April run will have full set of detectors, some built
inside support tube, for both HER and LER

Lost Particle Backgrounds

Expected to be quadratic with beam current
(linear term is possible from base pressure)

Detectors at various positions
- PIN diodes in 4 places on beam pipe
- Straw chamber at larger radius
- Crystal Ring (2 crystals) at still larger radius
- Water Cherenkov 4 meters upstream

Had 3 shifts in Fall dedicated to backgrounds vs I
- Half-strength Q4/5, 8.5 GeV
- Full-strength Q4/5, 8.5 GeV
- Full strength Q4/5, 9 GeV

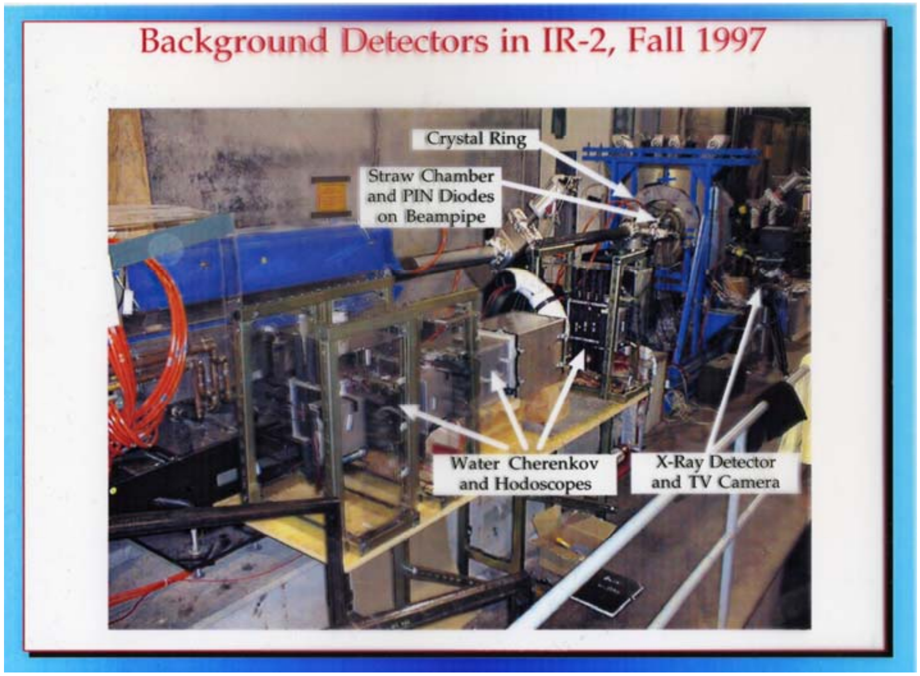
PIN diodes show large left-right effect from mask

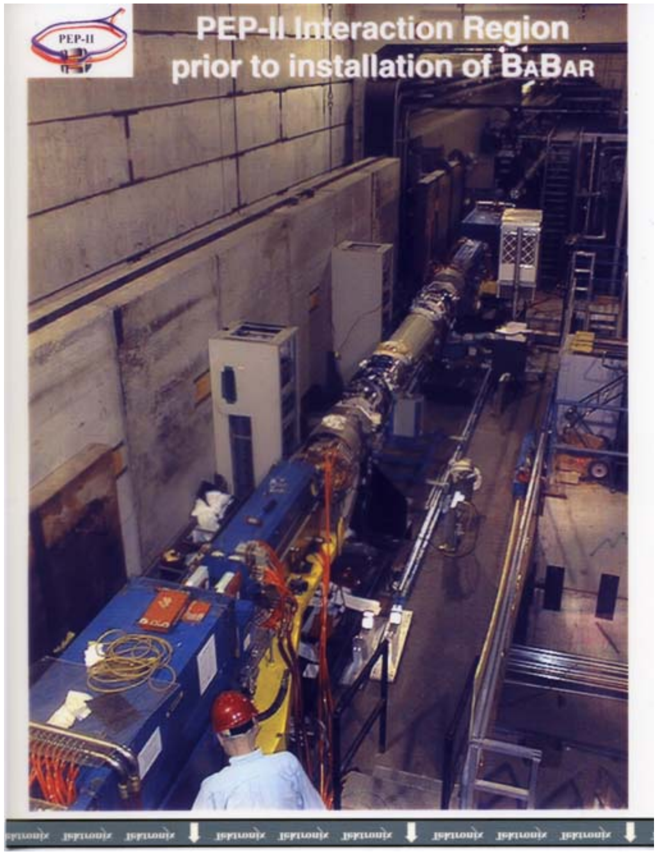
Dedicated runs have relatively small differences,
some evidence of improvement with time,
but non-dedicated runs typically much worse

Quadratic term always present, sometimes large,
but significant linear terms present too

Variation with position is plausible

1997


Background Detectors in IR-2, Fall 1997
Crystal Ring
Straw Chamber
and PIN Diodes
on Beampipe
Water Cherenkov
and Hodoscopes
X-Ray Detector
and TV Camera


PEP-II
PEP-II Interaction Region
prior to installation of BABAR

Background Detectors and Groups

Detector	Purpose	Groups
Solid State X-Ray Spectrometer	Synchrotron radiation spectrum	Colorado State U. + LBL
Silicon Diode Stacks	SR, lost-particle rate near beam pipe	Stanford U.
Straw Chamber (from Crystal Ball)	Lost-particles in tracking chamber	SLAC, Tennesee, Ecole Polytechnique
Scanning Crystal Ring	MeV photons from lost-particle showers	LAPP (Annecy) + Saclay (France)
Water Cherenkov + Scintillator Hodoscope	BaBar DIRC backgrounds	U. Cincinnati + LBL
Mini Time Projection Chamber	High-granularity tracking chamber near beam pipe	Orsay (France) +LBL + U. Cincinnati
Silicon Strip Detector (BaBar prototype)	SR, lost particles next to beam pipe	UCSD+UCSC+UCSB + LBL + INFN + ...
Calorimeter Module (BaBar prototype)	Energetic photons, tracks (>100 MeV)	SLAC

STRENGTH OF THE COLLABORATION

- IN RECOGNITION OF:
  - CHALLENGING PROJECT
  - NEED FOR EARLY,DESIGN-LEVEL PERFORMANCE

WE HAVE FORMED A STRONG COLLABORATION TO BUILD THIS MACHINE

SLAC AND LBL HAVE A LONG TRADITION OF DEVELOPING, DESIGNING AND BUILDING FRONTIER ACCELERATORS. STORAGE RINGS WERE PIONEERED AT SLAC; SLAC AND LBL JOINTLY DESIGNED AND BUILT PEP. LBL IS CURRENTLY BUILDING THE ALS SYNCHROTRON RADIATION RING.

THE ADDITION OF LLNL, WITH ITS EXCELLENT TECHNICAL AND SCIENTIFIC BASE, ADDS SUBSTANTIAL STRENGTH

- *B FACTORY JOINS THREE OF DOE's PREMIER LABS IN A FRONTIER SCIENCE ENDEAVOR.*

1991

10^{34} to 10^{36} cm^{-2} sec^{-1}

The mid 2000s to ??

NEEDS for Asymmetric machine (7Gev (e-) + 4 GeV (e+)).

- SuperB with peak luminosity of $10^{36} s^{-1} cm^{-2}$, integrating 75 ab-1 in 5 years.

Background not exceeding too much the present Babar, thanks to low current, crossing angle and a careful design of the Interaction Region.

- One beam 80% polarized (High Energy).

- Possibility of running asymmetric at Charm threshold.

Basic concepts

* Two options:

* High currents
  – Very high currents
  – Smaller damping time →High power components
  – Shorter bunches →Costly to operate
  – Crab cavities for head-on collision
  – Higher power

* *SuperB* exploits an alternative approach, with a new IP scheme:
  – Small emittance beams (ILC-DR like)
  – Large Piwinski angle and "*crab waist*"
  – Currents comparable or smaller than present Factories

→A lot of fine tuning!

SLAC

Talk of John Seeman: July 2008

PPA Particle Physics & Astrophysics

Super-B vs Super-KEKB

*

Notes:

SuperB length w/o spin rotators.

SuperKEKB luminosity assumes x2 gain from crab cavities.

SuperB luminosity arises from small emittance & small ß* compared to SuperKEKB

	Super*B*	SuperKEKB
Circumference (m)	1800	3016
Energy (GeV) (LER/HER)	4/7	3.5/8
Current (A)/beam	1.85	9.4/4.1
No. bunches	1251	5018
No. part/bunches	5.5×10^{10}	$12/5 \times 10^{10}$
θ (rad)	2x24	2x15
ε_x (nm-rad) (LER/HER)	2.8/1.6	24
ε_y (pm-rad) (LER/HER)	7/4	180
β_y^* (mm) (LER/HER)	0.22/0.39	3
β_x^* (mm) (LER/HER)	35/20	200
σ_y^* (μm) (LER/HER)	0.039	1
σ_x^* (μm) (LER/HER)	10/6	50
σ_z (mm)	5	3
L ($cm^{-2}s^{-1}$)	$1.\times 10^{36}$	$4.\times 10^{35}$

Super-B builds on the Successes of Past Accelerators

* PEP-II LER stored beam current (3.2 A in 1722 bunches (4 nsec) at 3.1 GeV at 23 nm with little ECI effect on luminosity.
* Low emittance lattices designed for ILC damping rings, PETRA-3, NSLC-II, and PEP-X. (few nm horizontal x few pm vertical)
* Very low emittance achieved in an ILC test ring: ATF.
* Successful crab-waist luminosity improvement at DAFNE in Frascati.
* Successful crab-cavity tests at KEKB at low currents.
* Spin manipulation tests in Novosibirsk.
* Efficient spin generation with a high current gun and spin transport to the final focus at the SLC.
* Successful two beam interaction region built by KEKB and PEP-II.
* Continuous injection works with the detector taking data (KEKB and PEP-II)

Conclusions

- In the talks that follow, you will get a better appreciation of how well the challenges were met at PEP-II
- In summary, the design expectations for daily integrated luminosity were exceeded by a factor of 7
  - not that it was easy! But as third generation e^+e^- storage rings we had a wealth of information to back up our design choices. The combination of outstanding accelerator and engineering talent and prudent management did the rest
- The situation with the SuperB factories is the same – applying the same principles as we did to PEP-II and KEKB is likely to lead to the same successful outcome